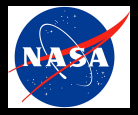
Snow and Ice Climatology of the Western United States and Alaska from MODIS

Thomas H. Painter, Chris Mattmann
Jet Propulsion Laboratory
California Institute of Technology

NCA update 20 November 2012

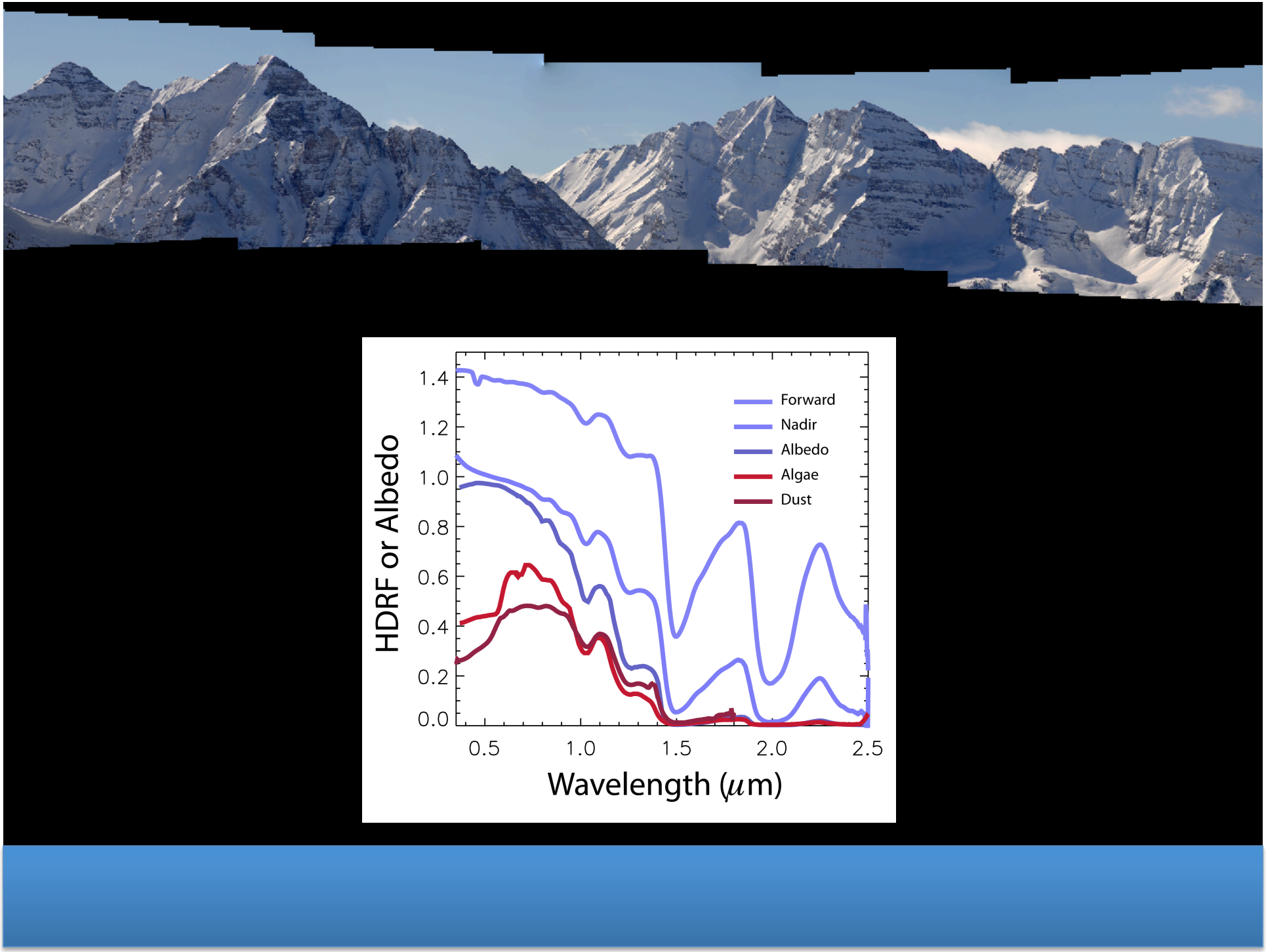


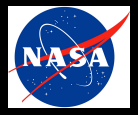
Further Investigators

- Karl Rittger, Caltech postdoctoral fellow
- Cameron Goodale, JPL/Caltech
- Andrew Hart, JPL/Caltech
- Paul Ramirez, JPL/Caltech
- Felix Seidel, Caltech postdoctoral fellow
- Paul Zimdars, JPL/Caltech

Outline

1. Fractional Snow Covered Area – MODSCAG
2. Dust/BC Radiative Forcing in Snow – MODDRFS
3. Annual Minimum Snow and Ice – MODICE
4. 8-day composites
5. NCA reports
6. AGU presentations


HDRF or Albedo
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
0.5
1.0
1.5
2.0
2.5
Wavelength (μm)
Forward
Nadir
Albedo
Algae
Dust

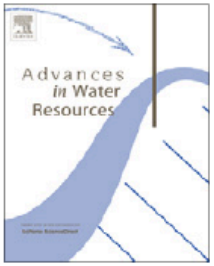


Advances in Water Resources xxx (2012) xxx–xxx

Contents lists available at SciVerse ScienceDirect

Advances in Water Resources

journal homepage: www.elsevier.com/locate/advwatres



Assessment of methods for mapping snow cover from MODIS

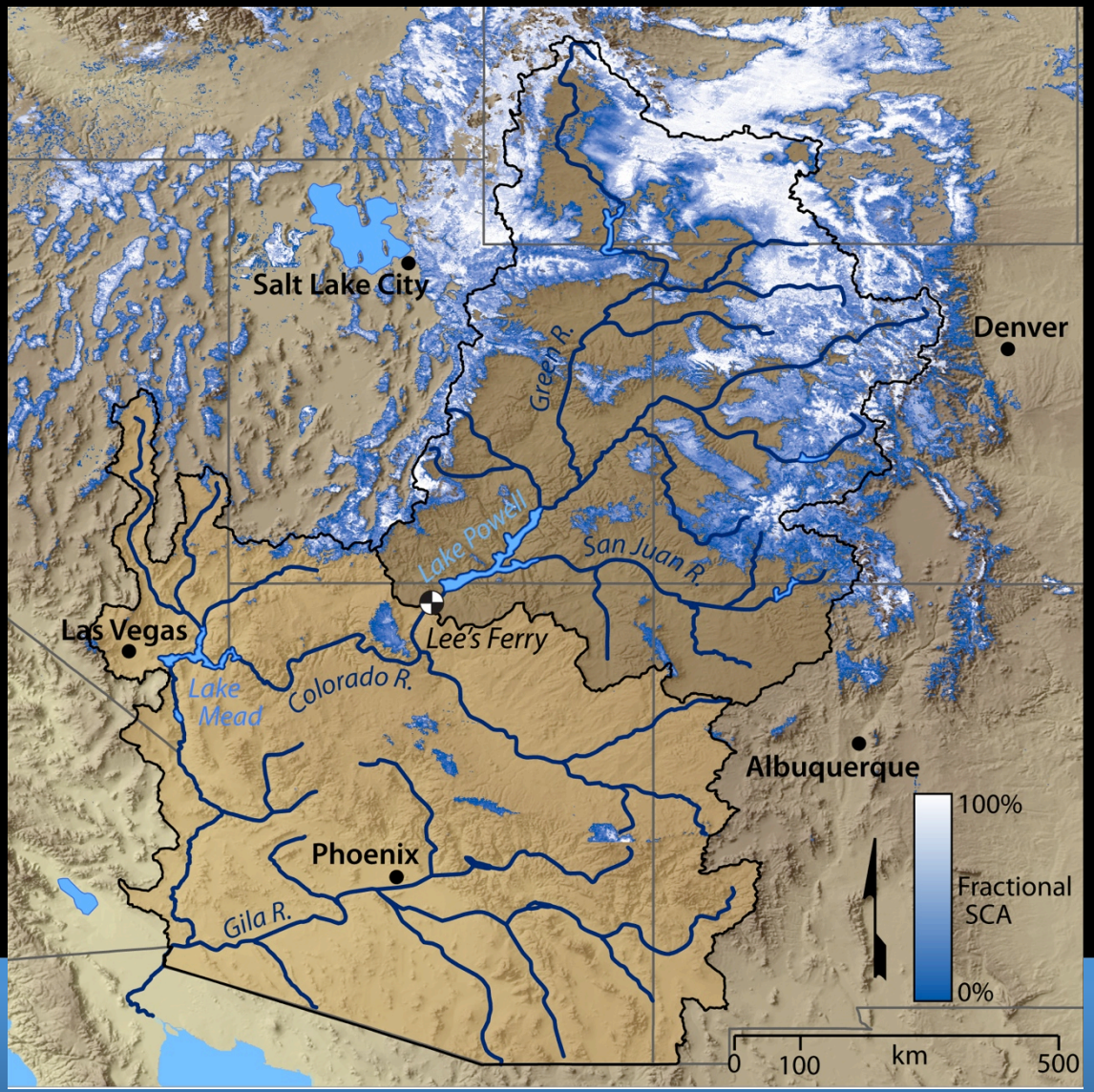
Karl Rittger [a], Thomas H. Painter [b], Jeff Dozier [a,*]

[a] Bren School of Environmental Science & Management, University of California, Santa Barbara, CA 93106-5131, United States
[b] Jet Propulsion Laboratory, California Institute of Technology, 4800 Oak Grove Dr, Pasadena, CA 91109, United States

MODSCAG Snow Cover

MODSCAG processing

- Western US complete (2000-present)
- Near real time processing ongoing
- Alaska processing ongoing
- Many users of the data already, accessed through JPL Snow Data Server



Time-Space Continuity

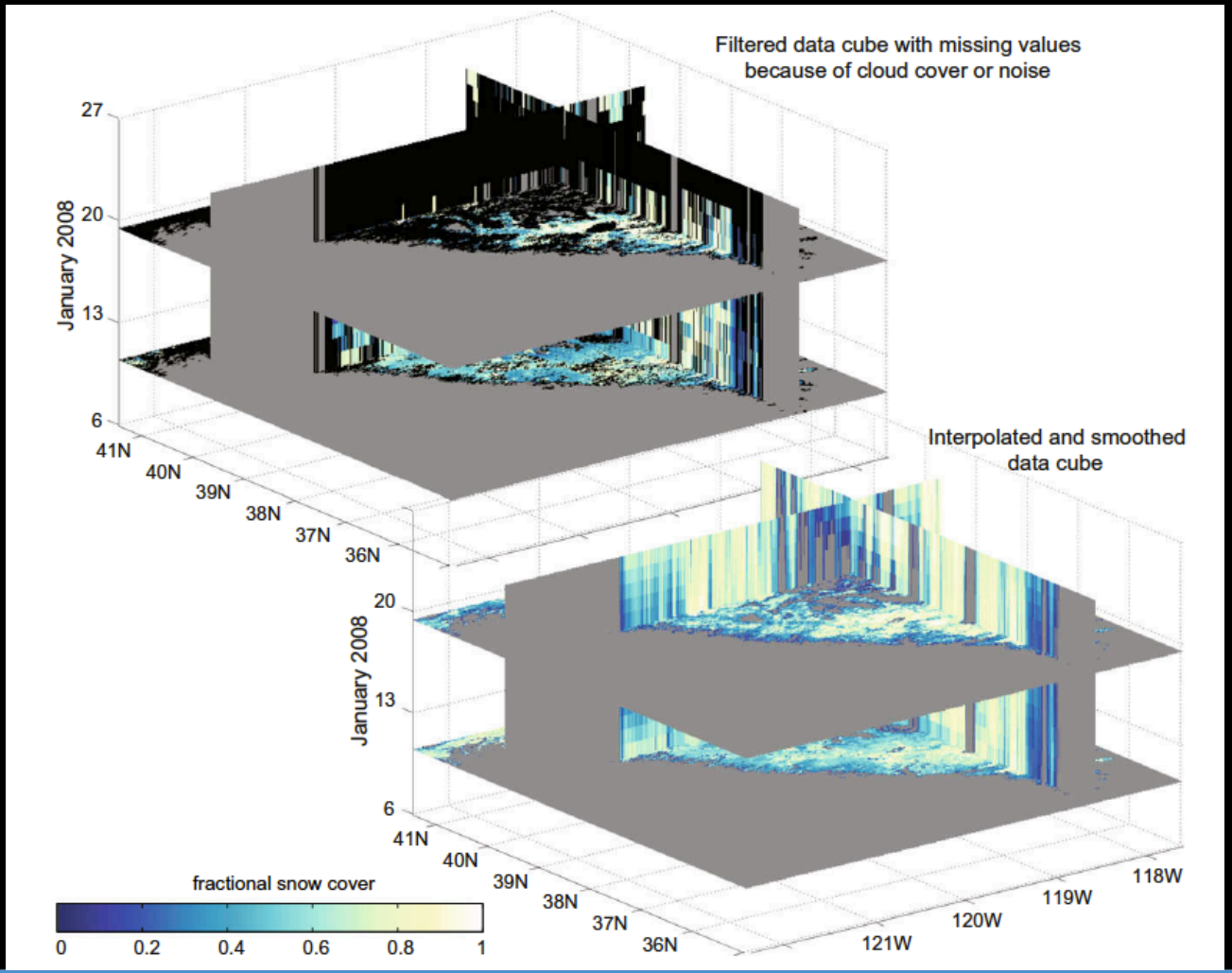
Value added products

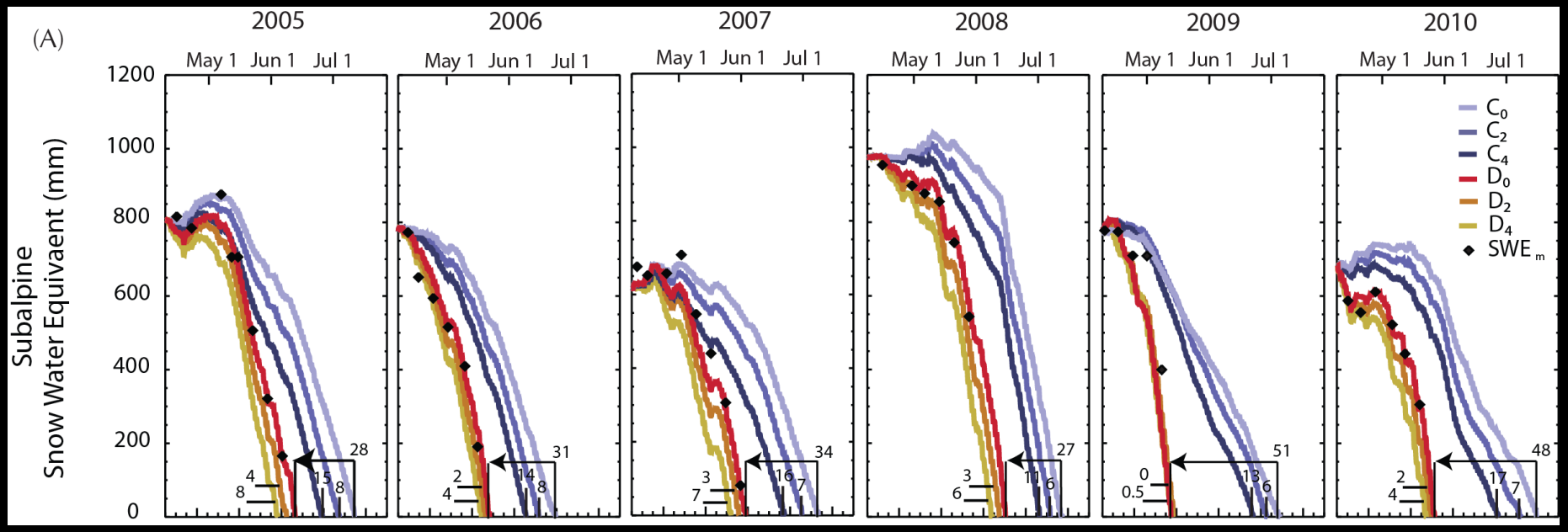
Time-space filtering of instantaneous MODSCAG retrievals to spatially and temporally continuous fields of fractional snow covered area and albedo.

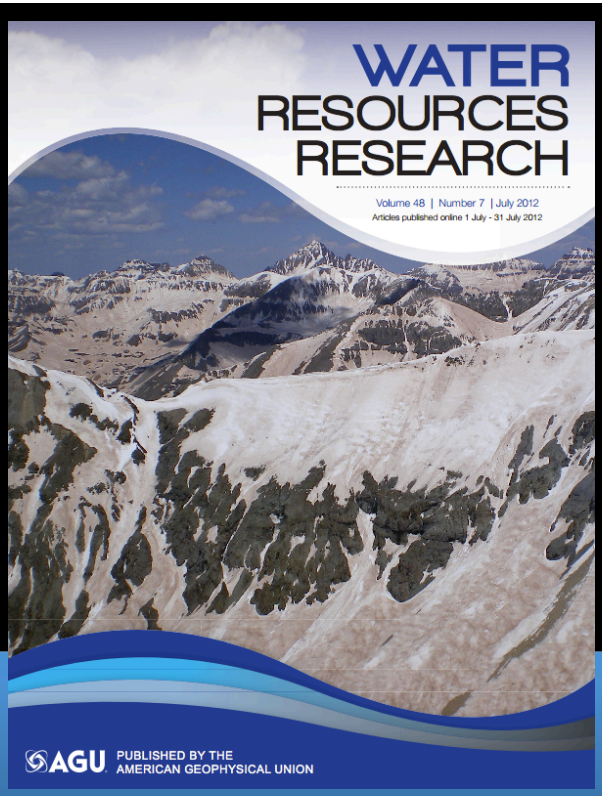
Constrained by cloud cover, sensor geometry

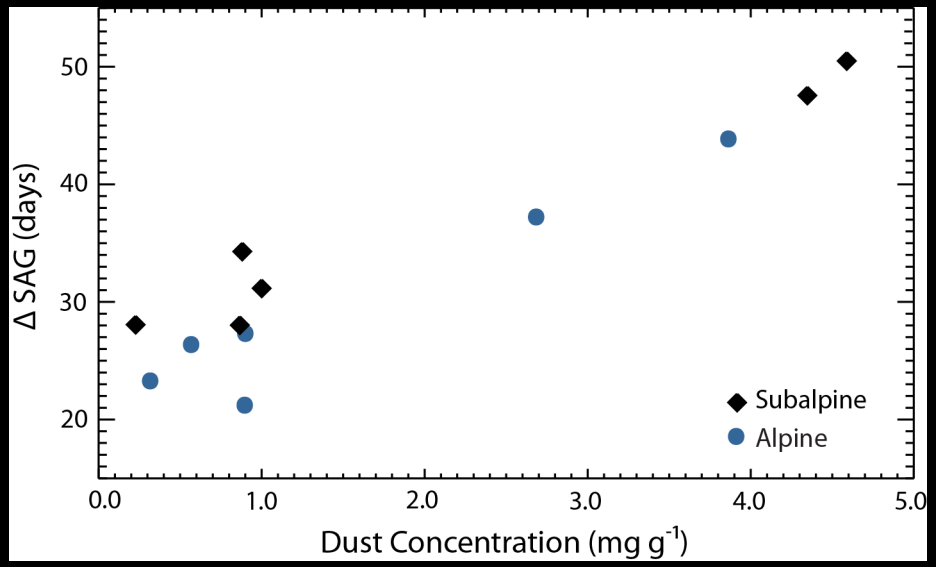
Available on Snow Data Server

Dozier et al 2008

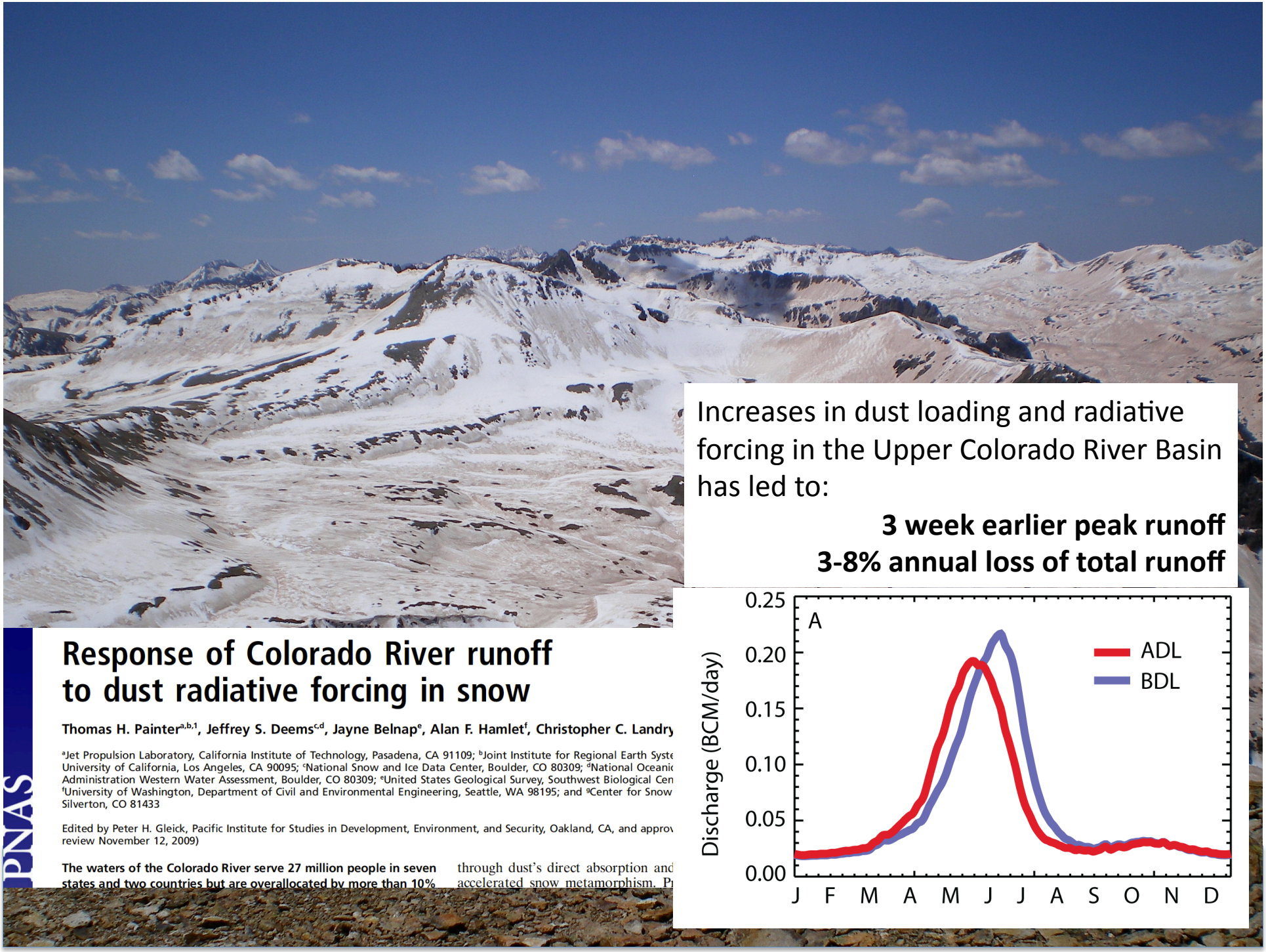








Skiles et al 2012 WRR



Increases in dust loading and radiative forcing in the Upper Colorado River Basin has led to:

3 week earlier peak runoff

3-8% annual loss of total runoff

PNAS

Response of Colorado River runoff to dust radiative forcing in snow

Thomas H. Painter[a,b,1], Jeffrey S. Deems[c,d], Jayne Belnap[e], Alan F. Hamlet[f], Christopher C. Landry

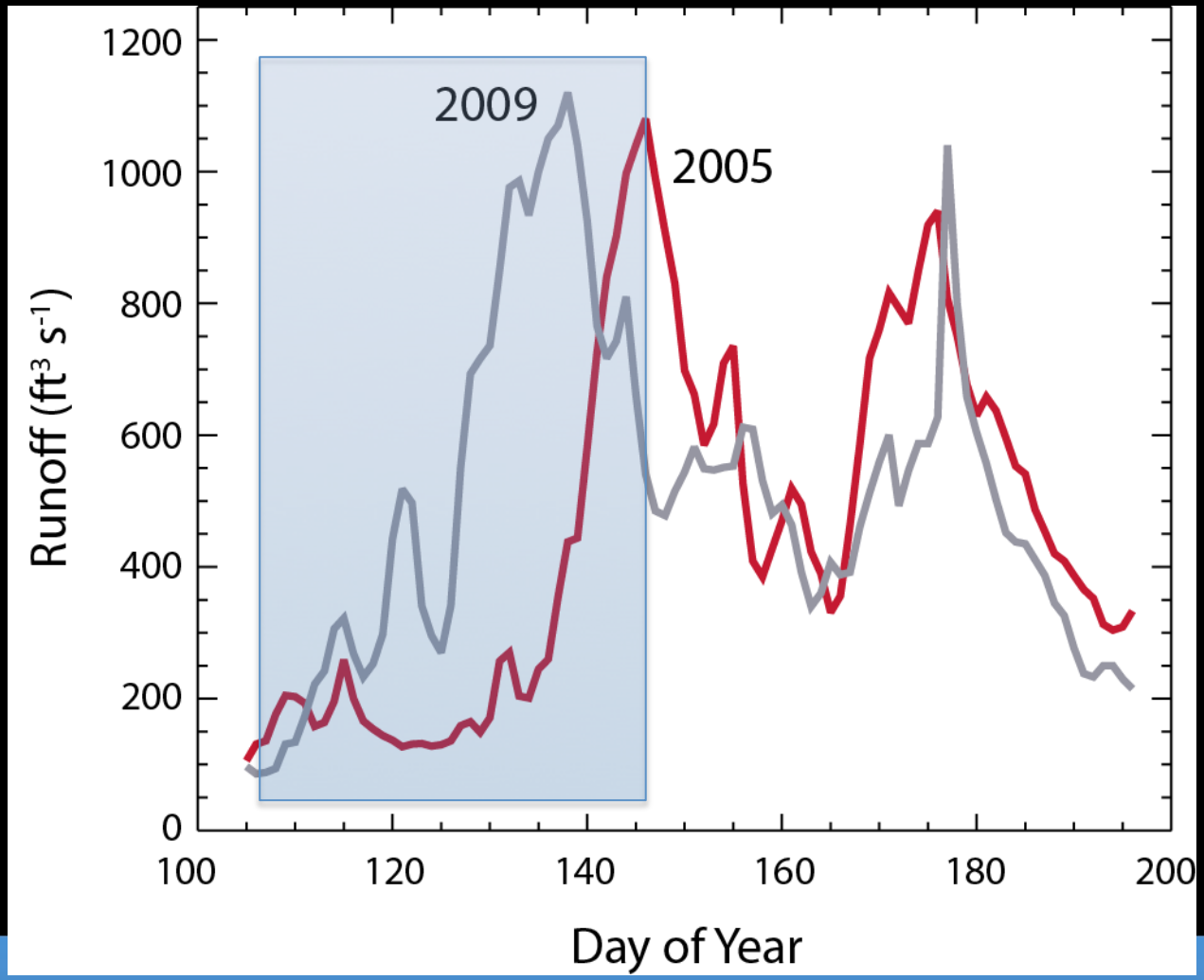
[a]Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA 91109; [b]Joint Institute for Regional Earth Syste
University of California, Los Angeles, CA 90095; [c]National Snow and Ice Data Center, Boulder, CO 80309; [d]National Oceanic
Administration Western Water Assessment, Boulder, CO 80309; [e]United States Geological Survey, Southwest Biological Cen
[f]University of Washington, Department of Civil and Environmental Engineering, Seattle, WA 98195; and [g]Center for Snow
Silverton, CO 81433

Edited by Peter H. Gleick, Pacific Institute for Studies in Development, Environment, and Security, Oakland, CA, and approv
review November 12, 2009)

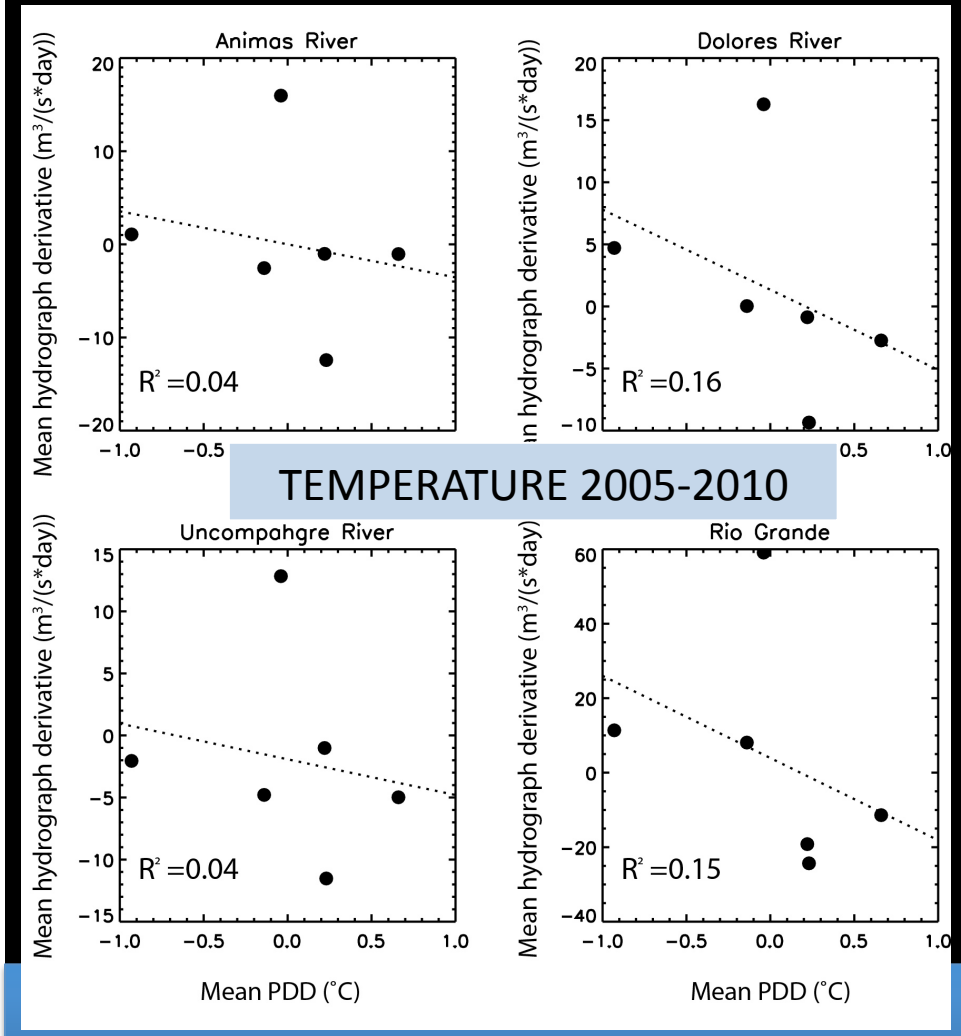
The waters of the Colorado River serve 27 million people in seven states and two countries but are overallocated by more than 10%

through dust's direct absorption and
accelerated snow metamorphism. P

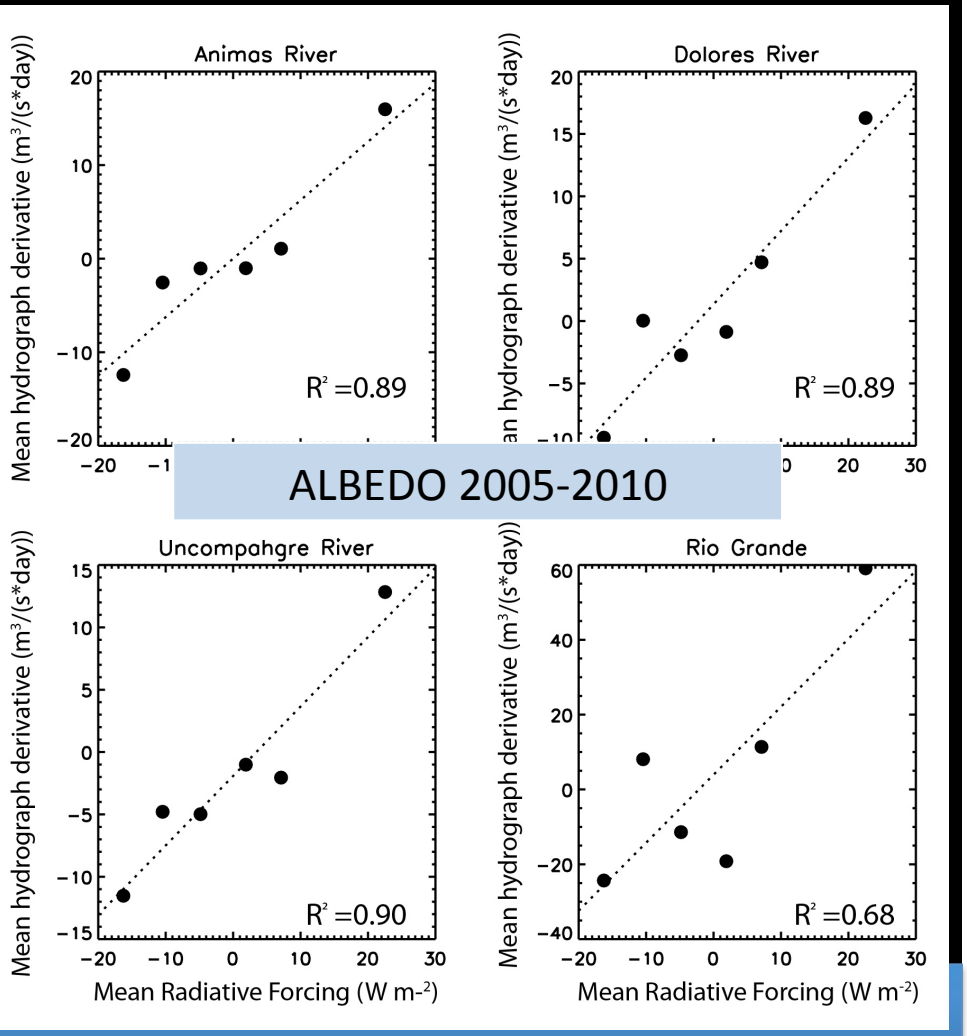
Controls on the interannual variability of the snowmelt runoff hydrograph?



Steepness of rising limb



TEMPERATURE 2005-2010



ALBEDO 2005-2010

Painter et al (in preparation)

How well do we know the radiative forcings and impact on snowmelt runoff?

GEOPHYSICAL RESEARCH LETTERS, VOL. 39, L17502, doi:10.1029/2012GL052457, 2012

Radiative forcing by light absorbing impurities in snow from MODIS surface reflectance data

Thomas H. Painter,[1] Ann C. Bryant,[2] and S. McKenzie Skiles[3]

Received 18 June 2012; revised 18 July 2012; accepted 23 July 2012; published 11 September 2012.

MODDRFS

MODIS Dust Radiative Forcing in Snow

Determine clean snow spectrum

$$NDGSI = \left(\frac{MODIS_2 - MODIS_5}{MODIS_2 + MODIS_5}\right)$$

With DEM, determine local illumination geometry

$$\cos\beta = \cos\theta_s \cos\theta_n + \sin\theta_s \sin\theta_n \cos\{\phi_s - \phi_n\}$$

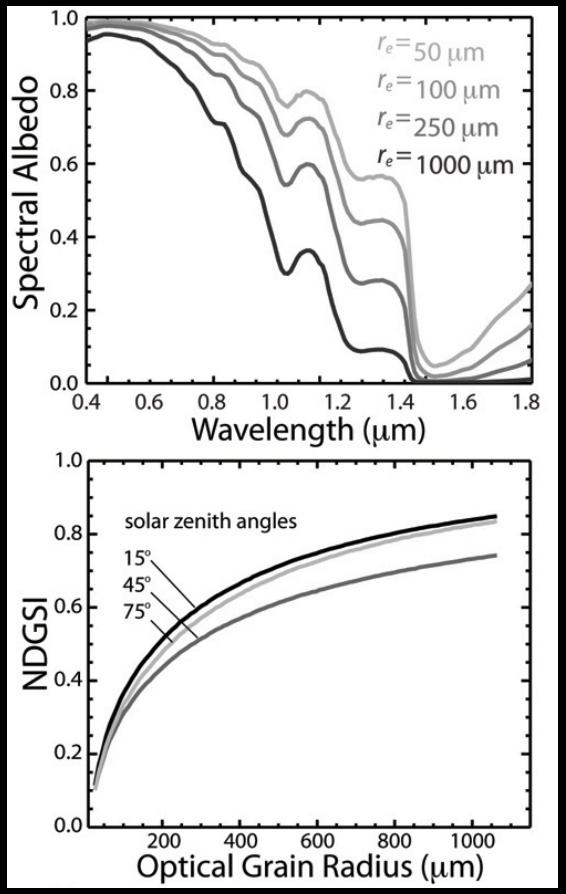
and local illumination

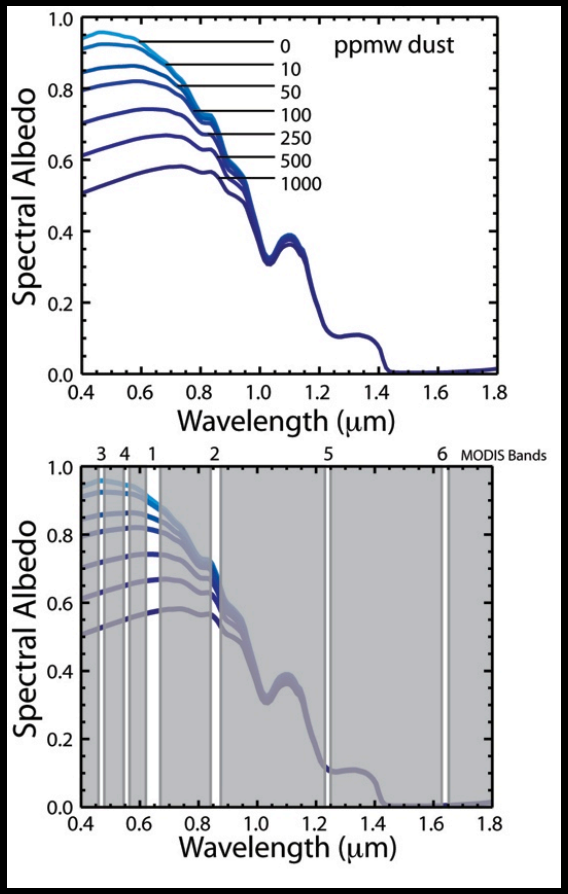
$$E_{corrected,\lambda} = \left(E_{direct,\lambda} \cos\beta\right) + E_{diffuse,\lambda}$$

and radiative forcing at 500 m scale

$$\alpha_{clean,\lambda} = c(\lambda;\theta_0;\theta_r,\phi_r;\zeta_{atm}) \cdot R(\lambda;\theta_0;\theta_r,\phi_r;\zeta_{atm})$$

$$F = \sum_{\lambda=0.35\mu m}^{\lambda=0.876\mu m} E_{corrected,\lambda}\left(\alpha_{clean,\lambda} - \alpha_{MODIS,\lambda}\right)\Delta\lambda$$



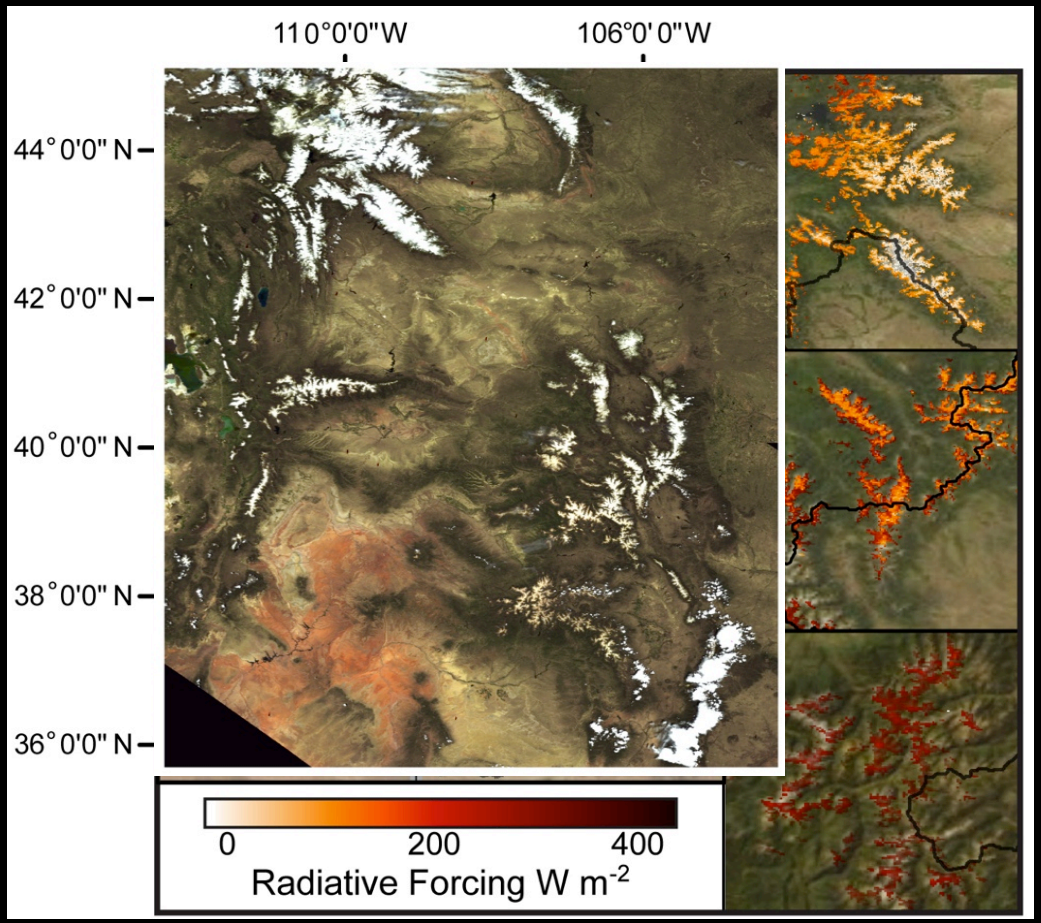


Painter et al *GRL* 2012a

MODDRFS Radiative Forcing

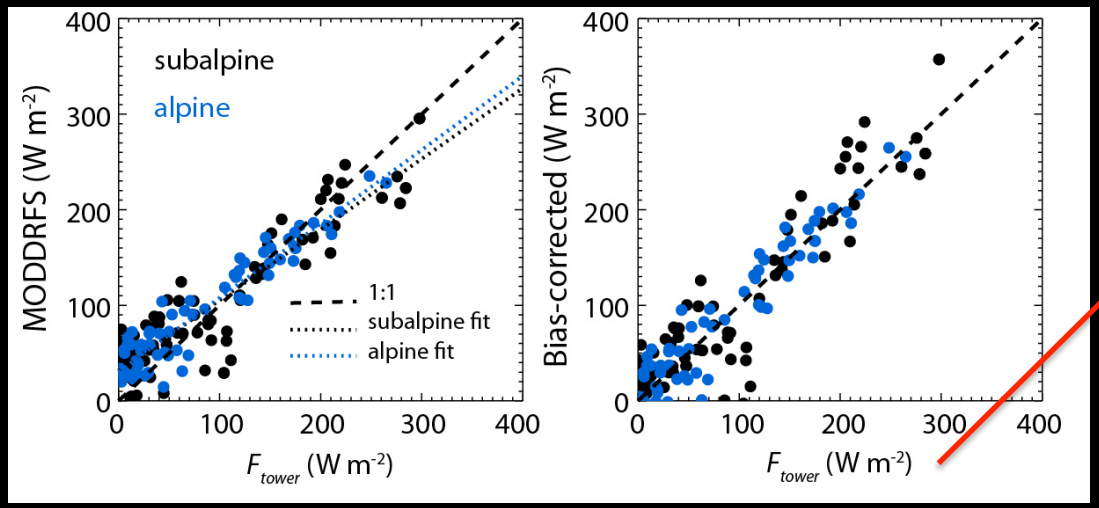
MODDRFS processing

- Western US complete (2000-present)
- Near real time processing ongoing
- Alaska processing ongoing
- Many users of the data already, accessed through JPL Snow Data Server



MODDRFS Dust Radiative Forcing **Colorado River Basin, Western US**

MODDRFS



RMSE 32 W m^{-2}; MAE 25 W m^{-2}

Painter et al 2007; Painter et al 2012a

MODDRFS Validation

MODIS Permanent Ice (MODICE)

GEOPHYSICAL RESEARCH LETTERS, VOL. 39, LXXXXX, doi:10.1029/2012GL053340, 2012

1 Automated mapping of Earth's annual minimum exposed snow 2 and ice with MODIS

3 Thomas H. Painter,[1] Mary J. Brodzik,[2] Adina Racoviteanu,[3] and Richard Armstrong[2]

4 Received 31 July 2012; revised 12 September 2012; accepted 19 September 2012; published XX Month 2012.

The Global Land Ice Measurements from Space (GLIMS) project has compiled digital glacier outlines and related metadata for the majority of the world's glaciers but inconsistency among product algorithms and time periods represented precludes the production of a consistently derived global dataset.

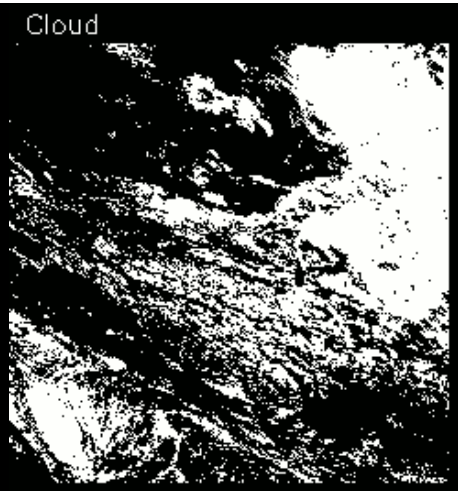
Currently a fundamental missing component of the world cryosphere inventory is a single systematically derived base map of the world' s glaciers and annual minimum snow cover, at any scale.

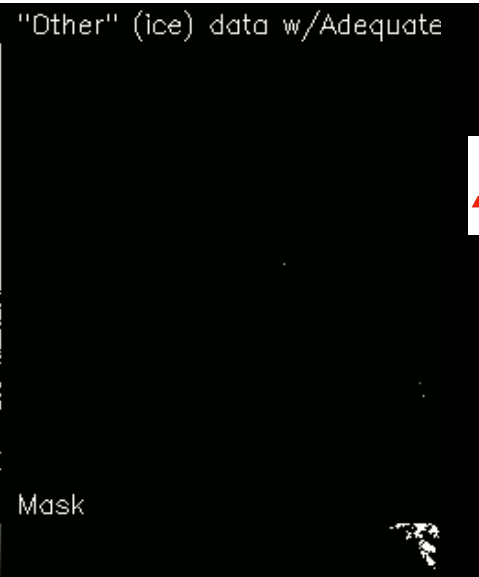
MODICE Annual Minimum Exposed Snow and Ice

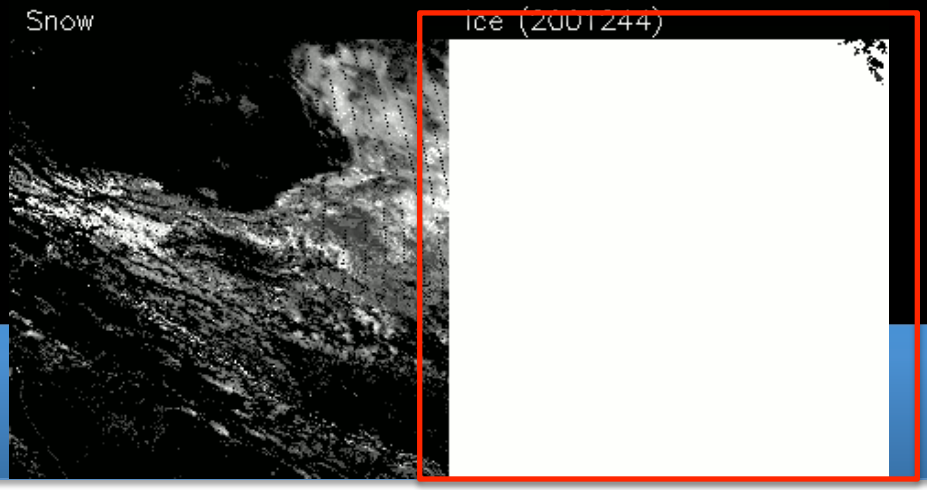
Annually resolved across the full EOS record.

Time series of MODSCAG retrievals to shrink-wrap annual minimum exposed snow and ice.

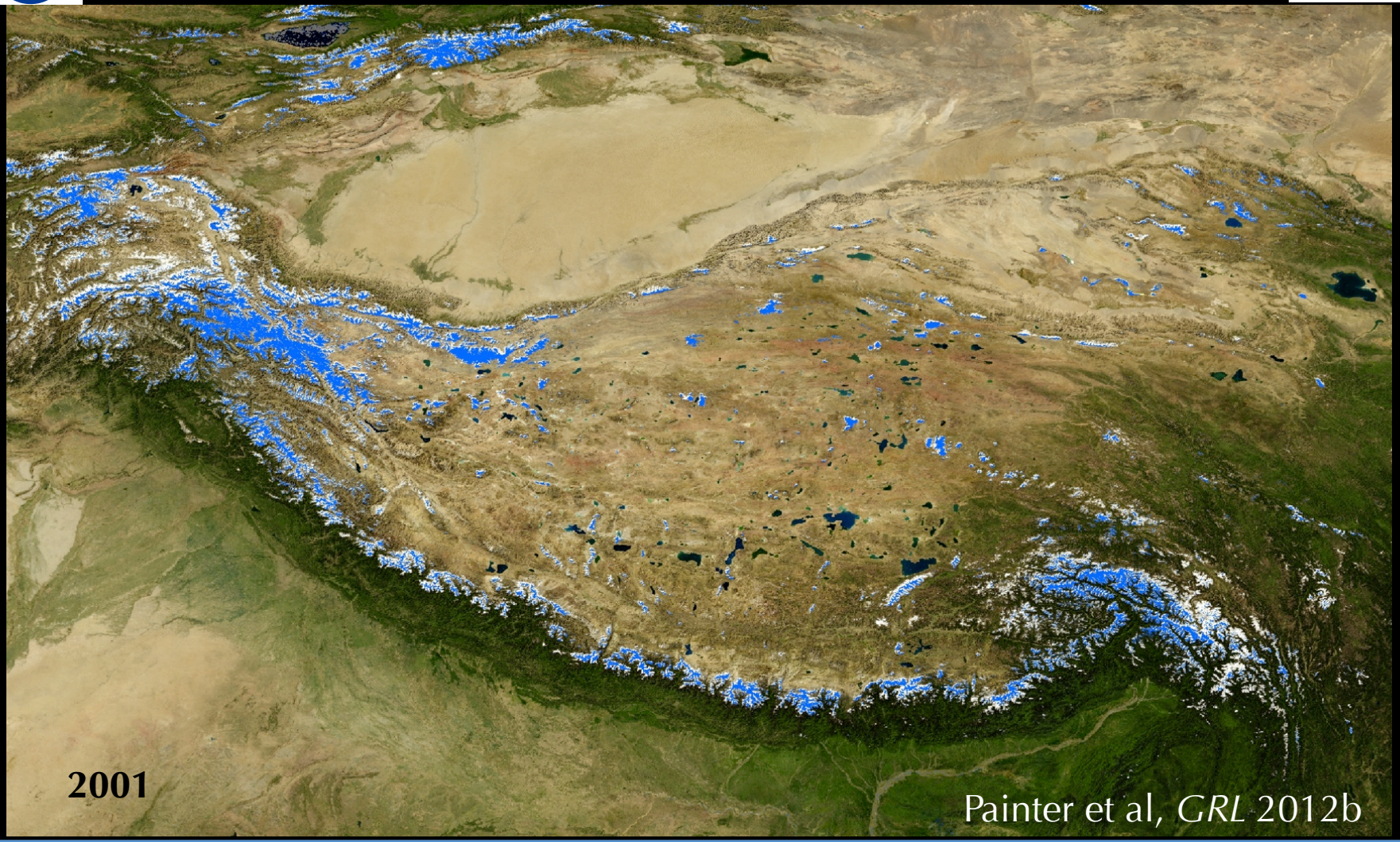
Constrained by cloud cover and sensor zenith, we chip away at snow/ice with non-snow pixels.



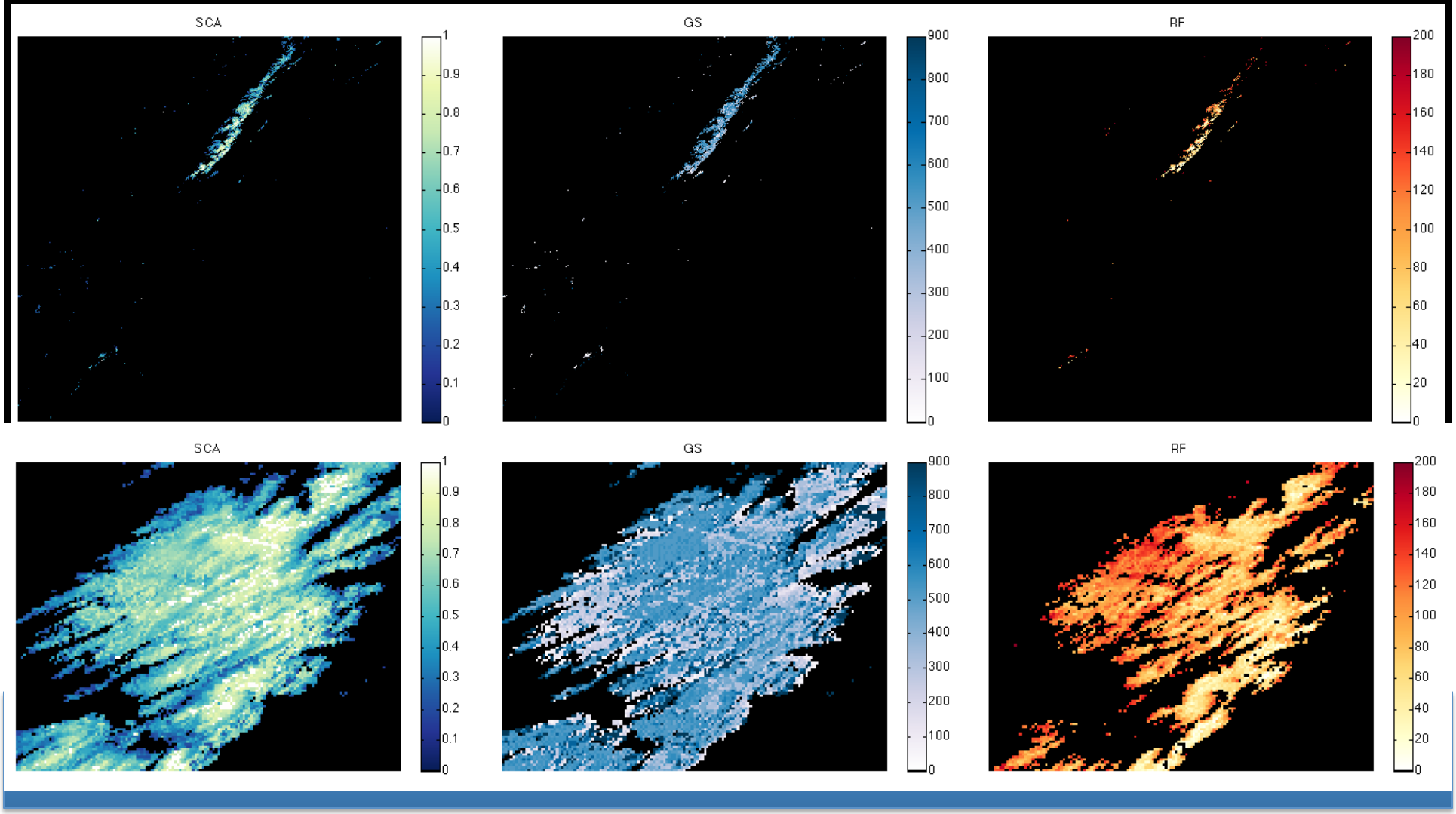




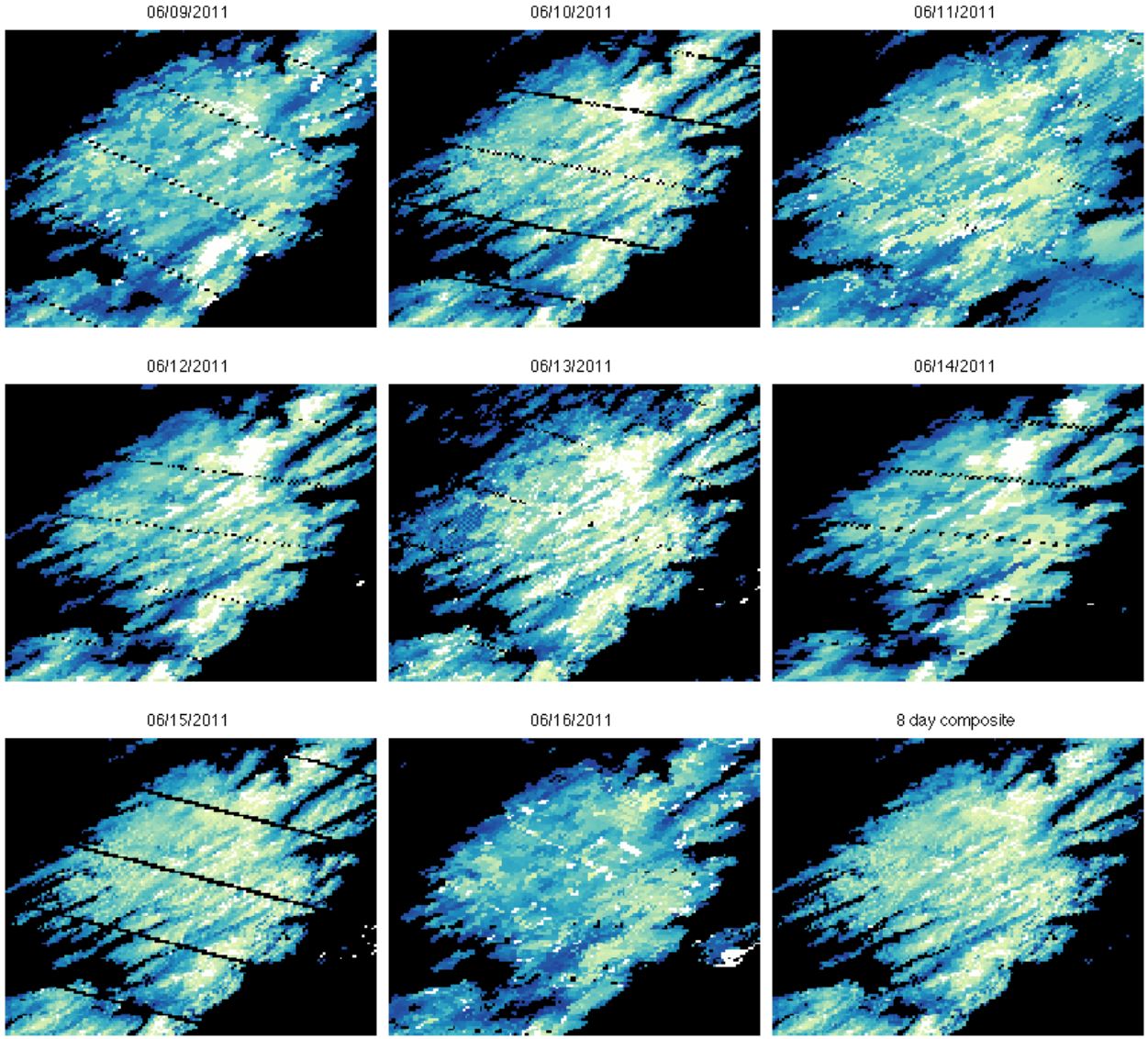
Karakoram/Himalaya/Tibetan Plateau


2001
Painter et al, *GRL* 2012b

All final products, June 09, 2011 h08v05 & Tuolumne

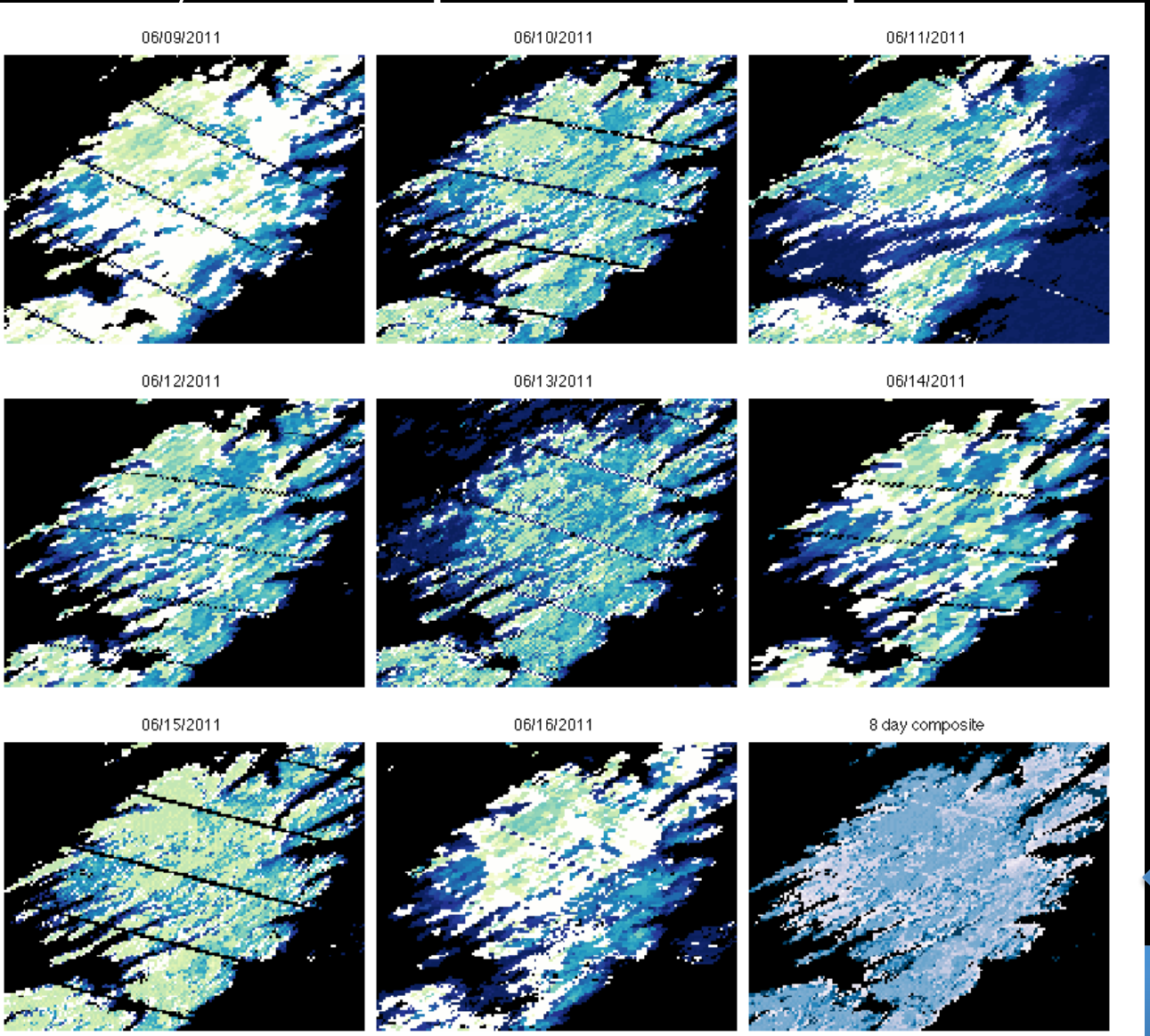


Snow Cover, June 09, 2011
8 days of input & final product



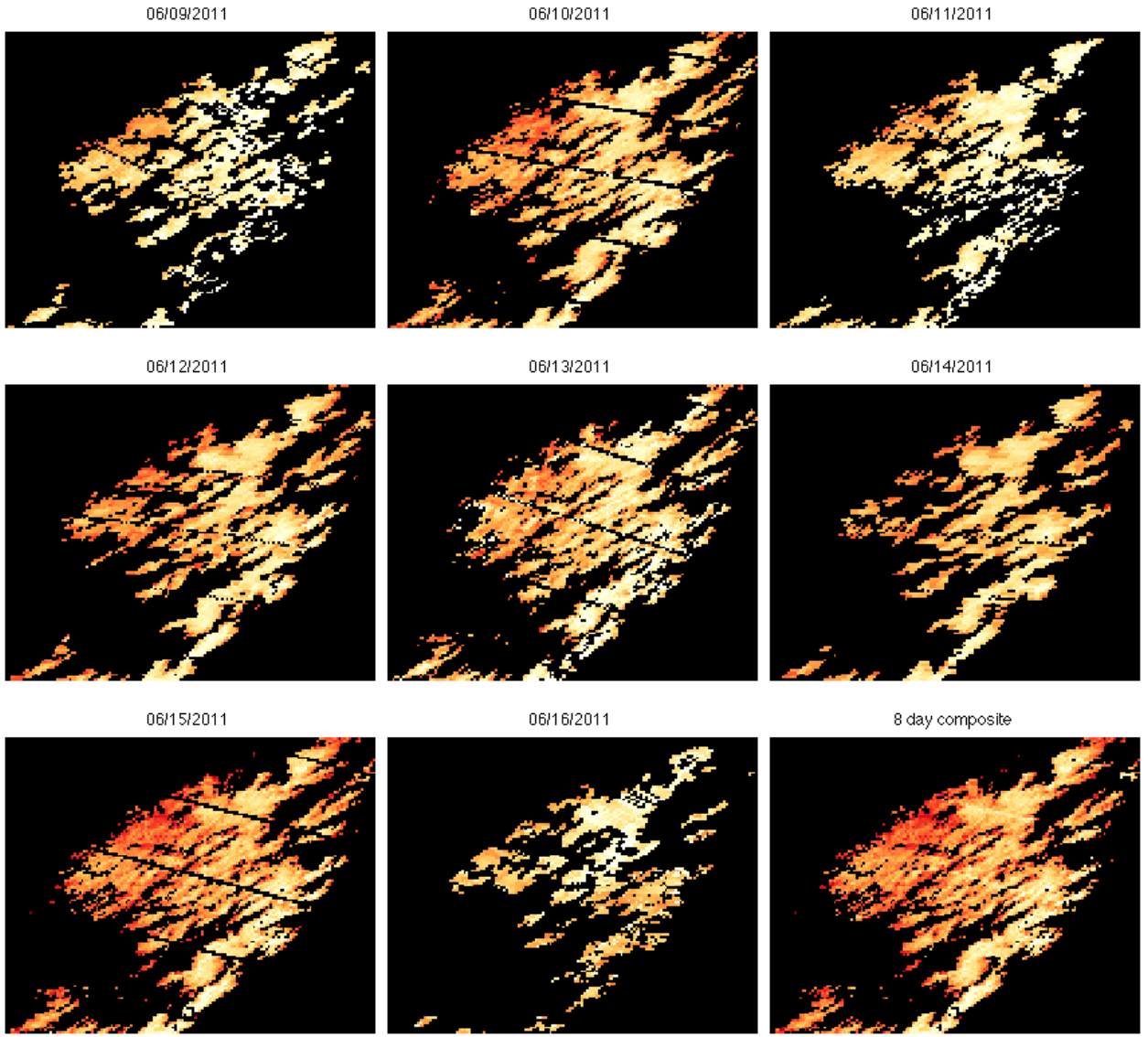
product

Grain Size, June 09, 2011
8 days of input & final product



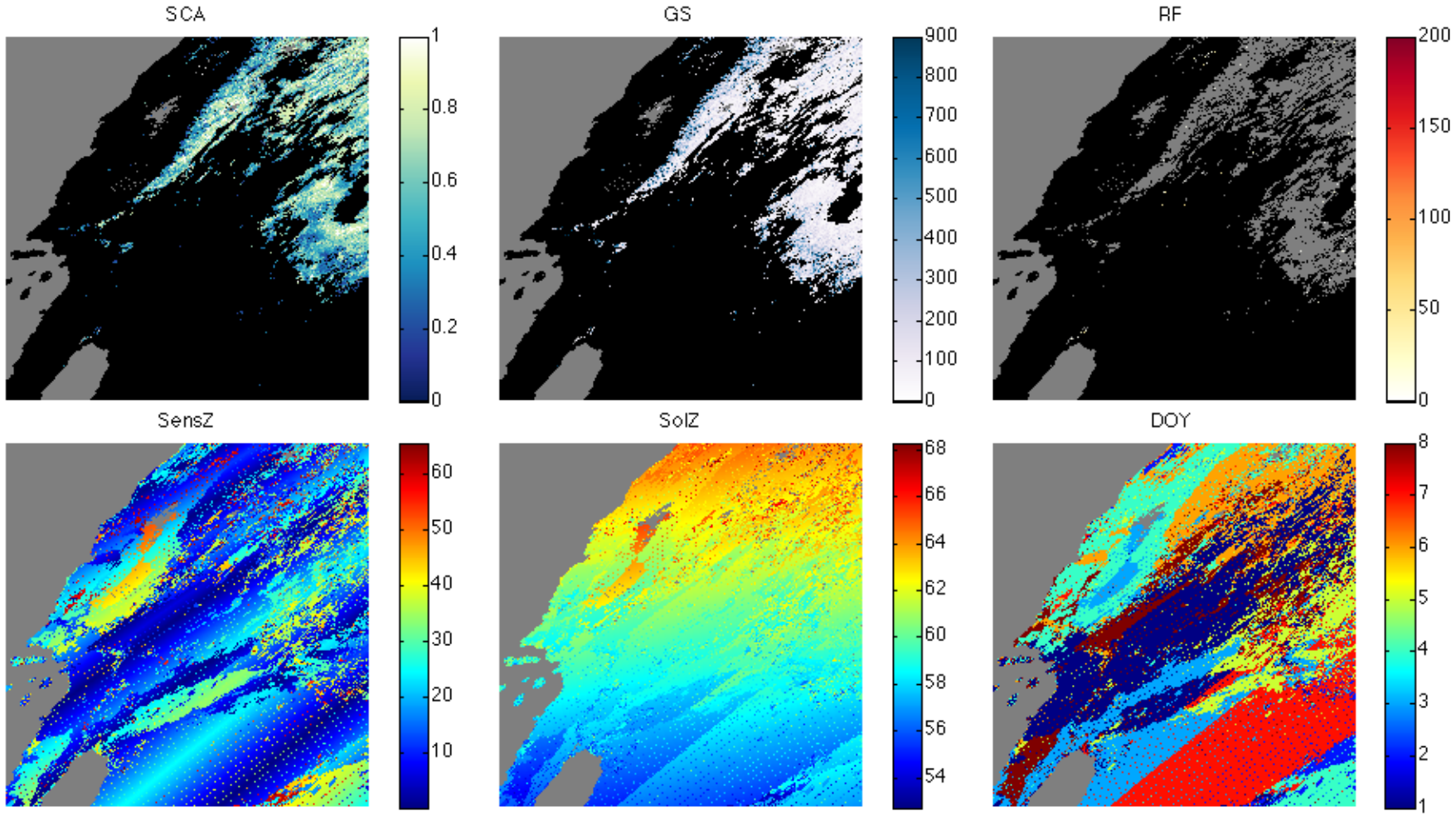
product

Radiative Forcing, June 09, 2011
8 days of input & final product



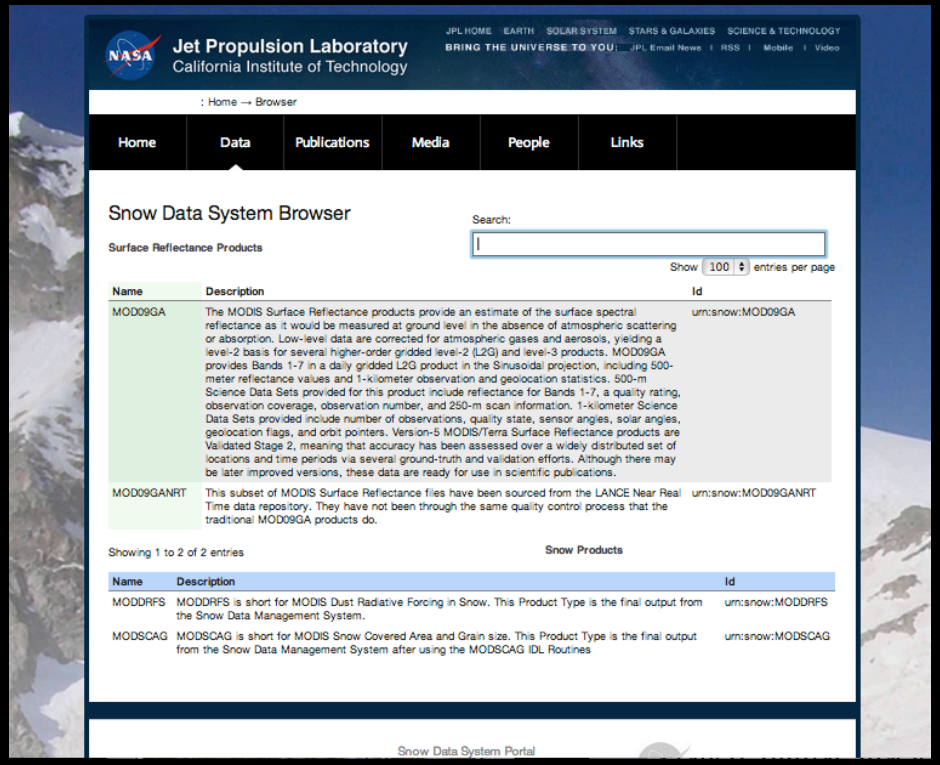
product

H08v05 2011001

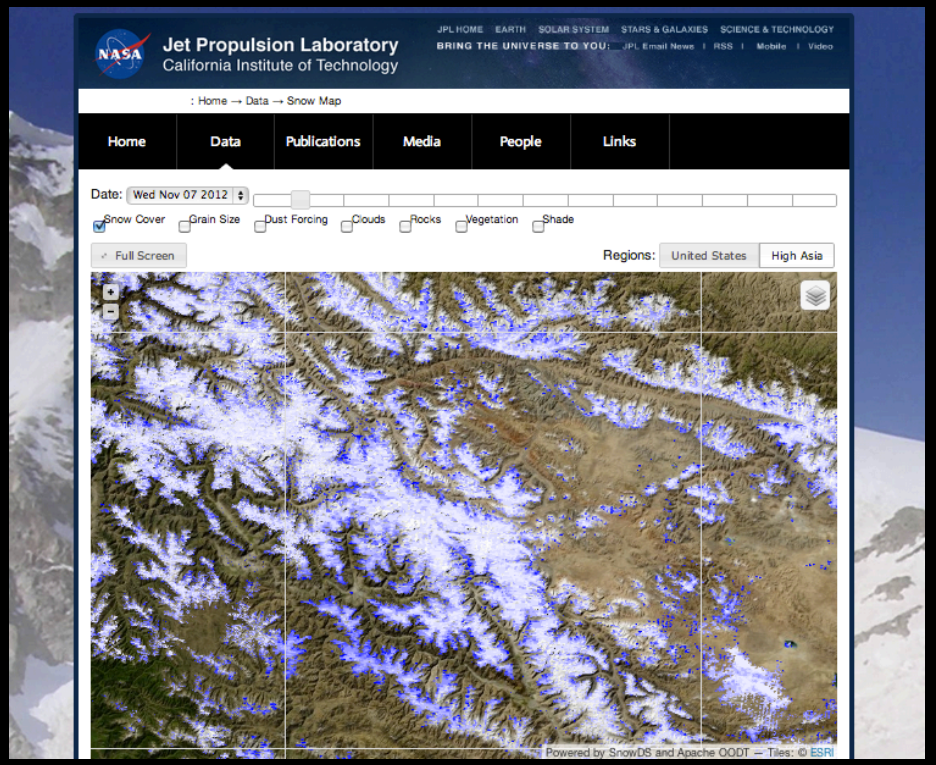


JPL Snow Data Server

MODIS historical processing

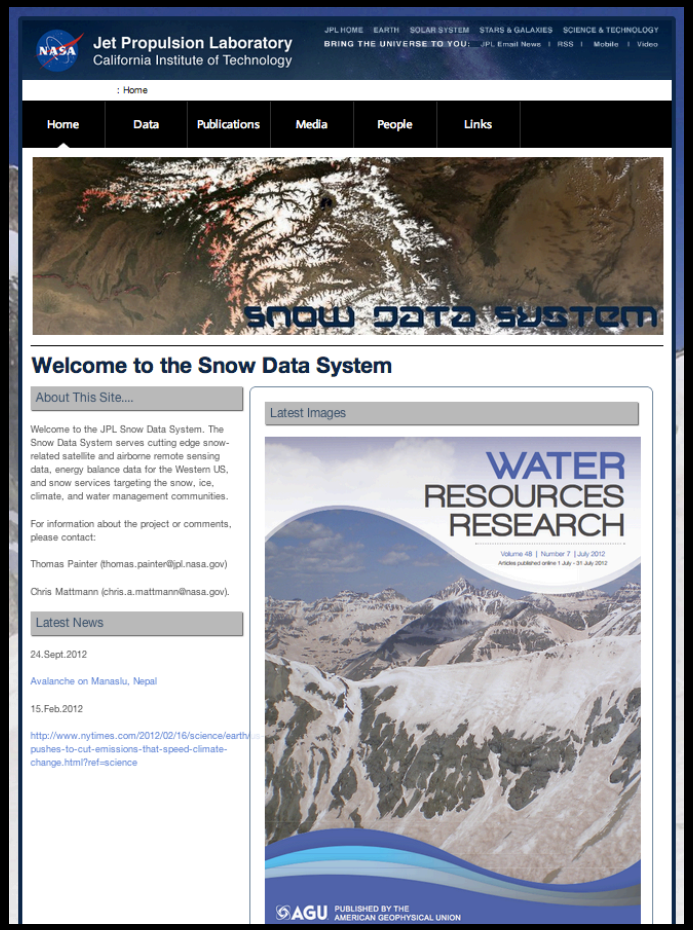


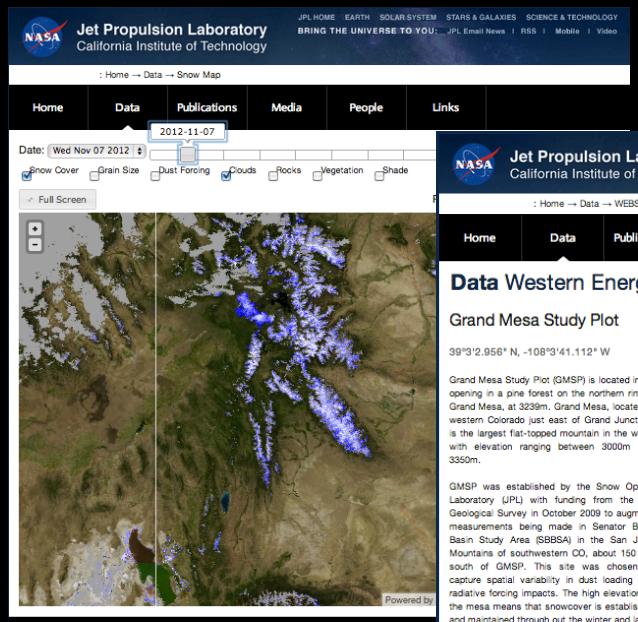
MODIS Near Real Time (NRT) processing

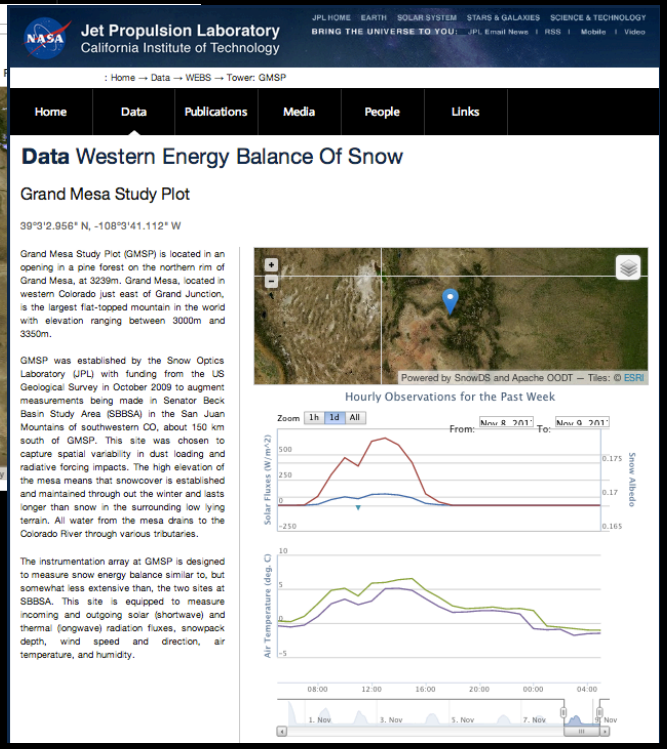


http://snow.jpl.nasa.gov/

JPL Snow Data Server







http://snow.jpl.nasa.gov/

NCA report

Assessment of Climate Change in the Southwest United States: A Technical Report Prepared for the U.S. National Climate Assessment

We have submitted our edits and author approvals for Chapter 4: *The Weather and Climate of the Southwest United States*

It is to be in press very soon.

AGU presentations

- Monday, 8AM-10AM, posters: IN11D-1475. Building a Snow Data Management System using Open Source Software (and IDL)
  Cameron E. Goodale; Chris A. Mattmann; Paul Ramirez; Andrew F. Hart; Thomas Painter; Paul A. Zimdars; Ann Bryant; Mary Jo Brodzik; McKenzie Skiles; Felix C. Seidel; Karl E. Rittger
- *Tuesday, 8AM-10AM, posters: C21C-0612. Validation and application of MODIS-derived clean snow albedo and dust radiative forcing*
  Karl E. Rittger; Ann C. Bryant; Felix C. Seidel; Edward H. Bair; McKenzie Skiles; Cameron E. Goodale; Paul Ramirez; Chris A. Mattmann; Jeff Dozier; Thomas Painter
- *Wednesday, 11:00AM, Moscone West 3007, C32B-06. Spatial variability and hydrologic response to dust radiative forcing of snow in the Upper Colorado River Basin (Invited)*
  Ann C. Bryant; Thomas Painter
- Friday, 1:40-4:00PM, posters: C53C-0865. Radiative forcing by light absorbing impurities in snow in the Upper Colorado River Basin using MODIS surface reflectance data *(Invited)*
  Ann C. Bryant; Thomas Painter; McKenzie Skiles
- *Friday, 5:15-5:30PM (REALLY!?!?!?!), 104 Moscone South: IN54B-06. High fidelity remote sensing of snow properties from MODIS and the Airborne Snow Observatory: Snowflakes to Terabytes (Invited)*
  Thomas Painter; Chris A. Mattmann; Mary Jo Brodzik; Ann C. Bryant; Cameron E. Goodale; Andrew F. Hart; Paul Ramirez; Karl E. Rittger; Felix C. Seidel; Paul A. Zimdars